Addendum to the State of Wisconsin's 1-hour Ozone Attainment Demonstration

This addendum contains two technical reports concerning modeling runs completed by the State of Wisconsin DNR. One document details results of a modeling run where Wisconsin point sources were modeled at the Clean Air Act levels for 2007 while sources in the rest of the domain were modeled at the NOx SIP Call level. The second document describes a modeling analysis to ascertain the impact of emissions in the Secondary Ozone Control Region on ozone formation in the Lake Michigan area.

Both of these modeling runs are extensions of the work completed by the Lake Michigan Air Director's Consortium (LADCO). All meteorological data, modeling domain size and structure, initial and boundary condition files etc. are the same as those used in LADCO modeling activities. Only certain emission files were changed to complete these runs. The same version of the UAM-V model (UAM-V version 1.24) was also used.

Wisconsin 1-hour Attainment Modeling

Overview of Modeling

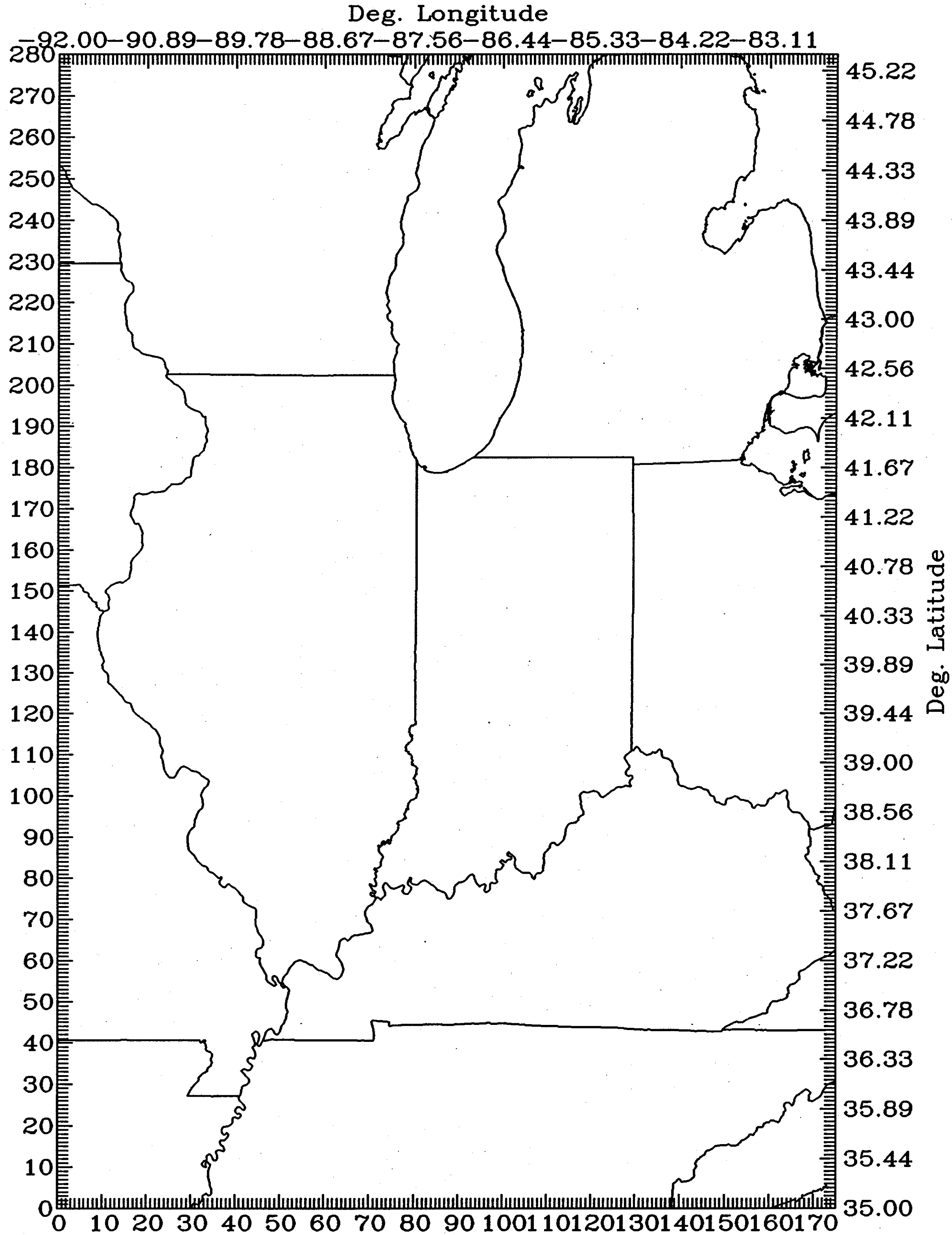
An additional state-of-the-art modeling analysis was performed by the State of Wisconsin DNR (in addition to modeling completed by LADCO) to support its 1-hour ozone attainment demonstration. The purpose of the additional modeling analysis was to determine whether the Lake Michigan states pass the 1-hour attainment test assuming the NOx SIP Call was implemented consistent with the recent court decision. This decision reinstated the application of USEPA's NOx SIP Call to major NOx sources in states upwind of Wisconsin. Wisconsin NOx sources were exempted because USEPA could not demonstrate that Wisconsin sources significantly contribute to violations of the 1-hour ozone standard in downwind states.

The Urban Airshed Model, version 1.24 (UAM-V) was used for the analysis. This is the same version used during OTAG and in the previous Midwest subregional modeling analysis.

The modeling domain and grid configuration used by Wisconsin DNR and LADCO, referred to as Grid M, is shown in Figure 1. The specifics of this grid are as follows:

Horizontal Resolution:	$1/9^o$ x $1/6^o$ long (approx. 12 km x 12 km)	
Vertical Resolution:	7 vertical layers (0-50, 50-100, 100-250, 250-500, 500-1000, 1500-2500, and 2500-4000 m)	
SW Corner:	-92.00 W	35.00 N
NE Corner:	-82.28 W	45.37 N
Number of Grid Cells:	58 x 93 x 7	

Figure 1


Deg. Longitude
-92.00 -90.89 -89.78 -88.67 -87.56 -86.44 -85.33 -84.22 -83.11
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0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170
45.22 44.78 44.33 43.89 43.44 43.00 42.56 42.11 41.67 41.22 40.78 40.33 39.89 39.44 39.00 38.56 38.11 37.67 37.22 36.78 36.33 35.89 35.44 35.00
Deg. Latitude

Two episodes were modeled: July 14 -21, 1991
July 7 - 18, 1995

These episodes were chosen because preliminary LADCO modeling indicated they are the most controlling in terms of attaining the 1-hour ozone standard in the Lake Michigan region.

There are three key model inputs: emissions, meteorology, and boundary conditions. The development of the emission inputs for this analysis are discussed next. A detailed discussion of all inputs can be found in LADCO's Technical Support Document titled "Midwest Subregional Modeling: 1-Hour Attainment Demonstration For Lake Michigan Area', June 2000.

Emissions

The emissions scenario for this run was to hold Wisconsin point sources at Clean Air Act (CAA) levels for 2007 while modeling the rest of the domain with NOx SIP Call controls for 2007. Point source emissions were projected to the year 2007 from a 1996 base level. Wisconsin's 2007 CAA controls included the incorporation of Phase II Acid Rain requirements.

Modeling the NOx SIP Call includes the CAA controls plus a NOx emission limit of 0.15 lbs NOx/mmBTU for electric generating unit boilers and turbines > 25 MV. Also, there is a 60% reduction requirement, from projected 2007 NOx emissions, for industrial boilers > 250 mmBTU/hr energy output. Additionally, motor vehicles were modeled with the Tier II tailpipe standards and low sulfur gasoline.

The difference in Wisconsin NOx emissions between the CAA level and the NOx Sip Call are shown in the table below.

Control Level	NOx Utility Emissions Tons/Day	NOx Non-Utility Emissions Tons/Day	Total NOx Tons/Day
Clean Air Act	323.60	116.95	440.55
Sip Call	115.58	93.68	209.25
Difference (CAA-SIP)	208.02	23.27	231.30

In this analysis we used the NOx SIP Call boundary conditions. We also made a 12.5% reduction in low level CO emissions consistent with the LADCO approach.

A few simplifying assumptions were also made:

1. We modeled Missouri and Georgia at the SIP Call level.
2. We made no adjustment in Texas NOx emissions.
3. We made no adjustments to Illinois and Indiana point source emissions.
4. We made no correction for internal combustion engines.

It is believed the effect of these assumptions is negligible.

Modeling Results

Figure 2 shows the peak 1-hour predicted ozone concentrations for the July 1991 episode. Although the episode is longer, the main six days of the episode are shown here. These plots are for the Lake Michigan sub-omain of the Grid M modeling grid. Peak values are predicted to be at or above the 1-hour standard on July 20 and 21. Peak values in the sub-domain are 130 ppb and 125 ppb, respectively.

Similarly, peak 1-hour plots for the July 1995 episode are shown in Figure 3. Areas of predicted ozone values above the 1-hour standard are evident on July 13, 14, and 15. Maximum values are 127 ppb, 127 ppb, and 130 ppb, respectively.

Attainment Test

In June of 1996 USEPA published guidance on how to apply the 1-hour attainment tests. This guidance ("Guidance on Use of Modeled Results to Demonstrate Attainment of the Ozone NAAQS", EPA-454/B-95-007, June 1996) identifies two acceptable tests for demonstrating attainment of the 1-hour ozone NAAQS: a deterministic test and a statistical test. The deterministic test is a conservative, simple means of assessing attainment. The statistical test is intended to make the modeled attainment test more closely reflect the form of the 1-hour NAAQS. This is done by considering the severity of selected episode days more explicitly and allowing modeled exceedances on severe days, and by considering the uncertainty inherent in modeling analyses and allowing use of supplementary information to determine whether attainment is likely (i.e., a weight-of-evidence determination).

Results from applying the attainment tests are shown in the following tables. Note, results from other LADCO runs, namely the NOx SIP Call run (SR12) and some variations thereof (SR12a, SR12b) are also shown for comparative purposes. The current modeling run of interest is named 'sipnowi'.

Deterministic Test

Test: Pass if daily max ozone in every surface grid cell for all days ≤ 124 ppb

Results:

	96bas	**SR12**	**SR12a**	**SR12b**	**sipnowi**
7-16-91	108	103	101	97	102
7-17-91	89	90	90	87	87
7-18-91	108	107	108	100	104
7-19-91	112	110	110	105	109
7-20-91	150	**130**	**129**	**125**	**129**
7-12-95	118	103	102	100	102
7-13-95	146	**128**	**127**	124	**126**
7-14-95	140	**128**	**128**	**125**	**126**
7-15-95	156	**135**	**134**	**130**	**130**
Number of exceedance days		**4**	**4**	**3**	**4**

Deterministic test is not passed.

Statistical Test

<u>Test:</u> Pass if three benchmarks are met. If one or more benchmarks are not met then may still pass depending on a "weight of evidence determination."

Benchmark 1

The number of modeled exceedance days in a subregion must be less than 3 or N-1, whichever is less. N is the number of severe days. For the four episodes in the LADCO modeling 10 of them are severe days. Thus, the number of allowed exceedance days within any subregion is 3.

Results

The maximum number of modeled exceedance days in any subregion is as follows:

SR12	SR12a	SR12b	sipnowi
1	1	1	1

Benchmark 2

Predicted daily maximum ozone concentrations may not exceed 130 ppb on days with allowed exceedances. These are days with an ExEx rate between 0.5 – 2.0/yr (i.e. days with a Cox-Chu ranking of 22 – 90).

Date	Rank	Allowed Value	SR12	SR12a	SR12b	sipnowi
7-16-91			103	101	97	102
7-17-91			90	90	87	87
7-18-91	6	144	107	108	100	104
7-19-91	47	130	110	110	105	109
7-20-91	75	130	130	129	125	129

7-12-95	31	130	103	102	100	102
7-13-95	12	137	128	127	124	126
7-14-95	5	146	128	128	125	126
7-15-95	16	135	135	134	130	130

The number of days with modeled exceedances greater than the allowed value are:

SR12	SR12a	SR12b	sipnowi
0	0	0	0

Benchmark 3

The number of grid cells > 124 ppb must be reduced by 80% on each severe day.

% improvement (Number of grid cells > 124 ppb)

Date	SR12	SR12a	SR12b	sipnowi
7-16-91				100
7-17-91				100
7-18-91				100
7-19-91				100
7-20-91	91	94	94	90
7-12-95				100
7-13-95	95	96	96	92
7-14-95	93	94	98	91
7-15-95	90	94	92	95

Attainment is demonstrated with the statistical test if all three benchmarks are passed. The above results indicate that for the July 1991 and July 1995 episodes, for the sipnowi strategy (other states at the SIP call level and Wisconsin at a lesser level), all three benchmarks are passed. Thereby, demonstrating attainment with the 1-hr ozone standard for these episodes.

Figure 2

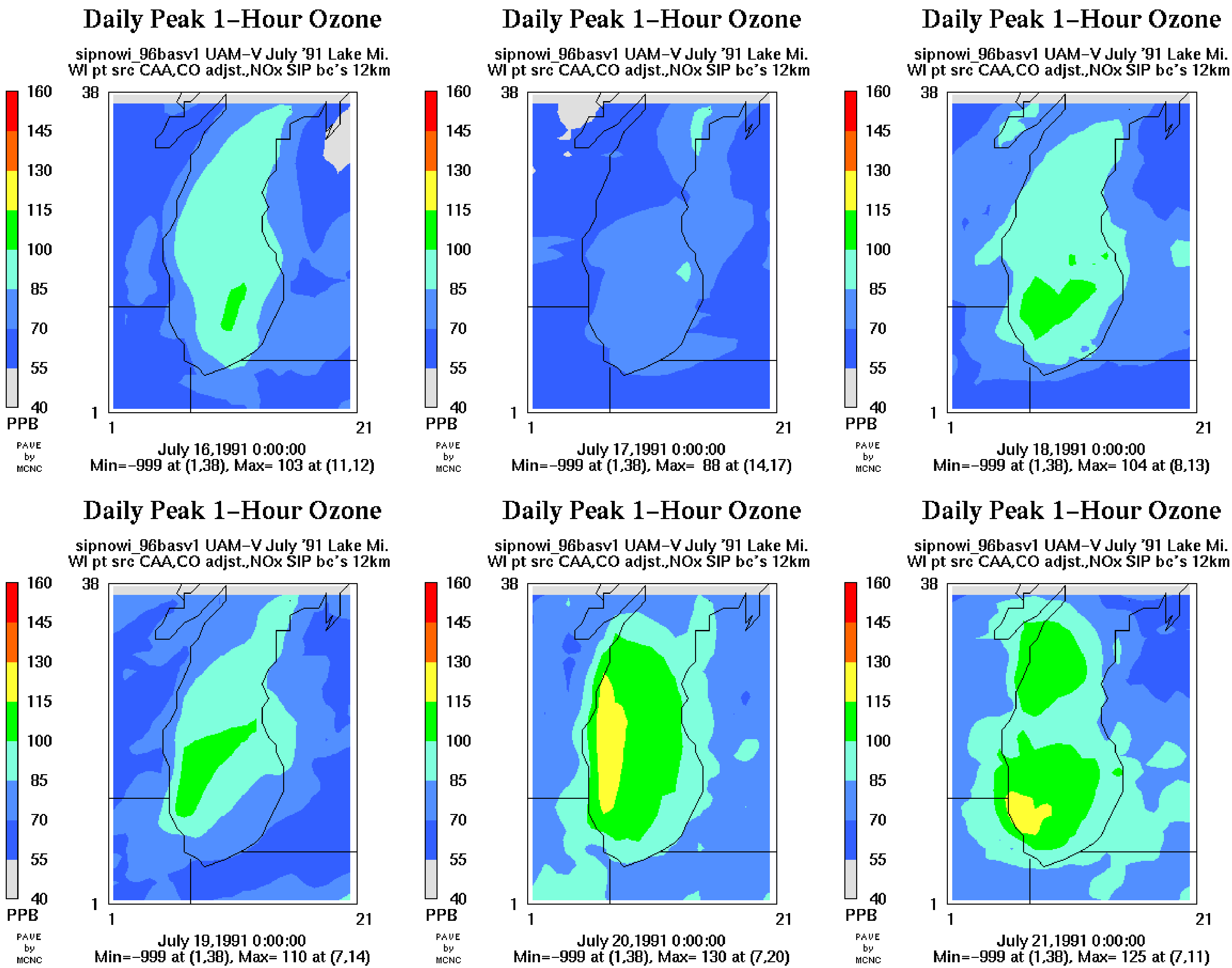
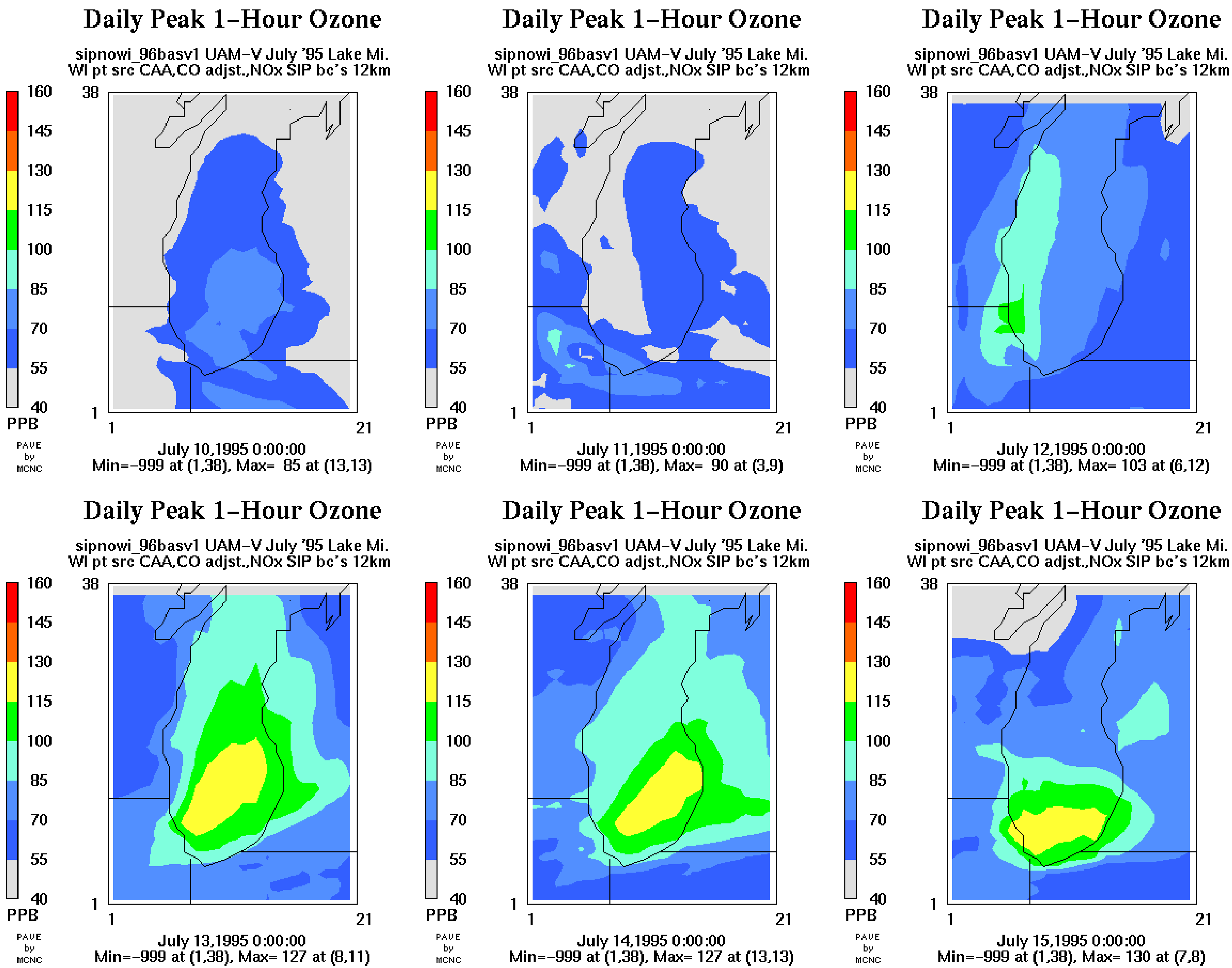

Daily Peak 1-Hour Ozone
sipnowi_96basv1 UAM-V July '91 Lake Mi.
WI pt src CAA,CO adjst.,NOx SIP bc's 12km
160 145 130 115 100 85 70 55 40
PPB
PAVE by MCNC
38 1 1 21
July 16,1991 0:00:00
Min=-999 at (1,38), Max= 103 at (11,12)
Daily Peak 1-Hour Ozone
sipnowi_96basv1 UAM-V July '91 Lake Mi.
WI pt src CAA,CO adjst.,NOx SIP bc's 12km
July 17,1991 0:00:00
Min=-999 at (1,38), Max= 88 at (14,17)
Daily Peak 1-Hour Ozone
sipnowi_96basv1 UAM-V July '91 Lake Mi.
WI pt src CAA,CO adjst.,NOx SIP bc's 12km
July 18,1991 0:00:00
Min=-999 at (1,38), Max= 104 at (8,13)
Daily Peak 1-Hour Ozone
sipnowi_96basv1 UAM-V July '91 Lake Mi.
WI pt src CAA,CO adjst.,NOx SIP bc's 12km
July 19,1991 0:00:00
Min=-999 at (1,38), Max= 110 at (7,14)
Daily Peak 1-Hour Ozone
sipnowi_96basv1 UAM-V July '91 Lake Mi.
WI pt src CAA,CO adjst.,NOx SIP bc's 12km
July 20,1991 0:00:00
Min=-999 at (1,38), Max= 130 at (7,20)
Daily Peak 1-Hour Ozone
sipnowi_96basv1 UAM-V July '91 Lake Mi.
WI pt src CAA,CO adjst.,NOx SIP bc's 12km
July 21,1991 0:00:00
Min=-999 at (1,38), Max= 125 at (7,11)

Figure 3


Daily Peak 1-Hour Ozone
sipnowi_96basv1 UAM-V July '95 Lake Mi.
WI pt src CAA,CO adjst.,NOx SIP bc's 12km
160 145 130 115 100 85 70 55 40
PPB
PAVE by MCNC
July 10,1995 0:00:00
Min=-999 at (1,38), Max= 85 at (13,13)
Daily Peak 1-Hour Ozone
sipnowi_96basv1 UAM-V July '95 Lake Mi.
WI pt src CAA,CO adjst.,NOx SIP bc's 12km
July 11,1995 0:00:00
Min=-999 at (1,38), Max= 90 at (3,9)
Daily Peak 1-Hour Ozone
sipnowi_96basv1 UAM-V July '95 Lake Mi.
WI pt src CAA,CO adjst.,NOx SIP bc's 12km
July 12,1995 0:00:00
Min=-999 at (1,38), Max= 103 at (6,12)
Daily Peak 1-Hour Ozone
sipnowi_96basv1 UAM-V July '95 Lake Mi.
WI pt src CAA,CO adjst.,NOx SIP bc's 12km
July 13,1995 0:00:00
Min=-999 at (1,38), Max= 127 at (8,11)
Daily Peak 1-Hour Ozone
sipnowi_96basv1 UAM-V July '95 Lake Mi.
WI pt src CAA,CO adjst.,NOx SIP bc's 12km
July 14,1995 0:00:00
Min=-999 at (1,38), Max= 127 at (13,13)
Daily Peak 1-Hour Ozone
sipnowi_96basv1 UAM-V July '95 Lake Mi.
WI pt src CAA,CO adjst.,NOx SIP bc's 12km
July 15,1995 0:00:00
Min=-999 at (1,38), Max= 130 at (7,8)

Secondary Ozone Control Region Modeling

Overview of Modeling

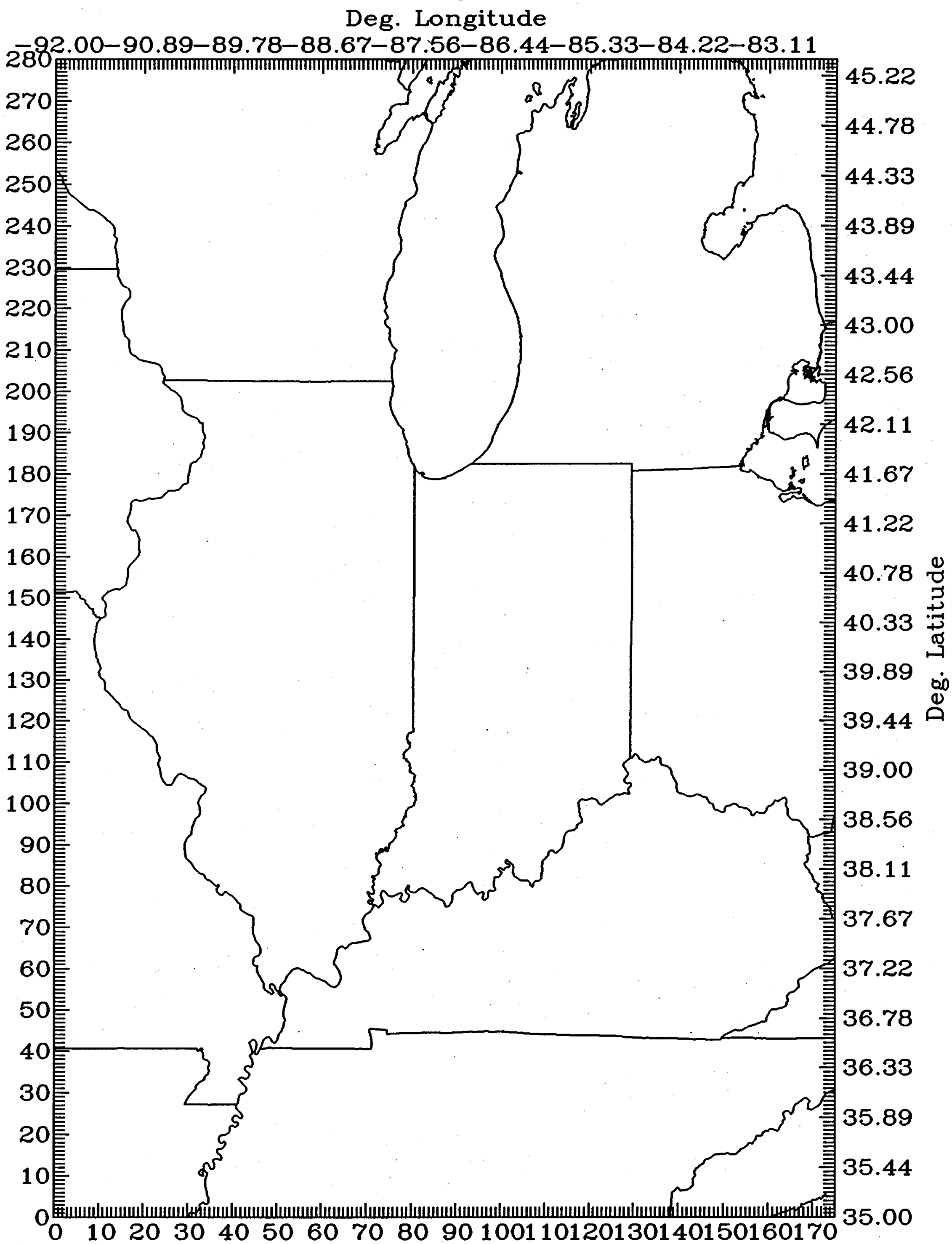
An additional state-of-the-art modeling analysis was performed by the State of Wisconsin DNR (in addition to modeling completed by LADCO) to support its 1-hour ozone attainment demonstration. The purpose of the additional modeling analysis was to determine the spatial extent and magnitude of the impact of the NOx emissions in the Secondary Ozone Control Region (SOCR) on ozone formation in the Lake Michigan area. The Urban Airshed Model, version 1.24 (UAM-V) was used for the analysis. This is the same version used during OTAG and in the previous Midwest subregional modeling analysis.

The modeling domain and grid configuration used by Wisconsin DNR and LADCO, referred to as Grid M, is shown in Figure 1. The specifics of this grid are as follows:

Horizontal Resolution:	$1/9^{o}$ x $1/6^{o}$ long (approx. 12 km x 12 km)	
Vertical Resolution:	7 vertical layers (0-50, 50-100, 100-250, 250-500, 500-1000, 1500-2500, and 2500-4000 m)	
SW Corner:	-92.00 W	35.00 N
NE Corner:	-82.28 W	45.37 N
Number of Grid Cells:	58 x 93 x 7	
Two episodes were modeled:	July 14 -21, 1991 July 7 - 18, 1995	

These episodes were chosen because they reflect high ozone conditions with west-southwest winds. This makes it possible to ascertain the impact of emissions from the SOCR on the main non-attainment area in Wisconsin and other counties in the Lake Michigan region.

Figure 1


Deg. Longitude
-92.00 -90.89 -89.78 -88.67 -87.56 -86.44 -85.33 -84.22 -83.11
280
270
260
250
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210
200
190
180
170
160
150
140
130
120
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90
80
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50
40
30
20
10
0
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170
45.22
44.78
44.33
43.89
43.44
43.00
42.56
42.11
41.67
41.22
40.78
40.33
39.89
39.44
39.00
38.56
38.11
37.67
37.22
36.78
36.33
35.89
35.44
35.00
Deg. Latitude

There are three key model inputs: emissions, meteorology, and boundary conditions. The development of the emission inputs for this analysis are dicussed here. A detailed discussion of all inputs can be found in LADCO's Technical Support Document titled "Midwest Subregional Modeling: 1-Hour Attainment Demonstration For Lake Michigan Area', June 2000.

Emissions

The modeling analysis consisted of "zeroing out" the NOx (NO and NO_2) emissions in the SOCR. Both point source and area source NOx emissions were set to zero, including whatever biogenic NOx might be present. However, this amount is quite small compared to anthropogenic NOx emissions. This was done using SAI's emission utility programs "emscor" and "ptscor". While "zeroing out" the emissions may not be a realistic scenario, it does provide a good "signal" concerning the spatial impact, and magnitude of that impact, of NOx emissions in the SOCR.

The boundary of the SOCR is quite irregular. The area was approximated using 12 km wide grid cells. By doing so, the boundary could not be matched exactly but most of the SOCR is accounted for.

Emissions from a known modeling run were used as the "basecase." For this analysis the "basecase" emissions scenario was "sipnowi_96basv1." The area source emission files from this scenario were input to the emscor program. Similarly, the point source emissions files were input to the ptscor program. The new "zeroed out" files were given the scenario name "sipnowi_96basv1_zero." These files were then used as input to the UAM-V model run.

Effect of NOx emissions from the SOCR

Differences in the NOx emissions, for the two scenarios, from area sources, for a weekday, were approximately 400 tons per day. For elevated point sources, the weekday difference was about 165 tons per day.

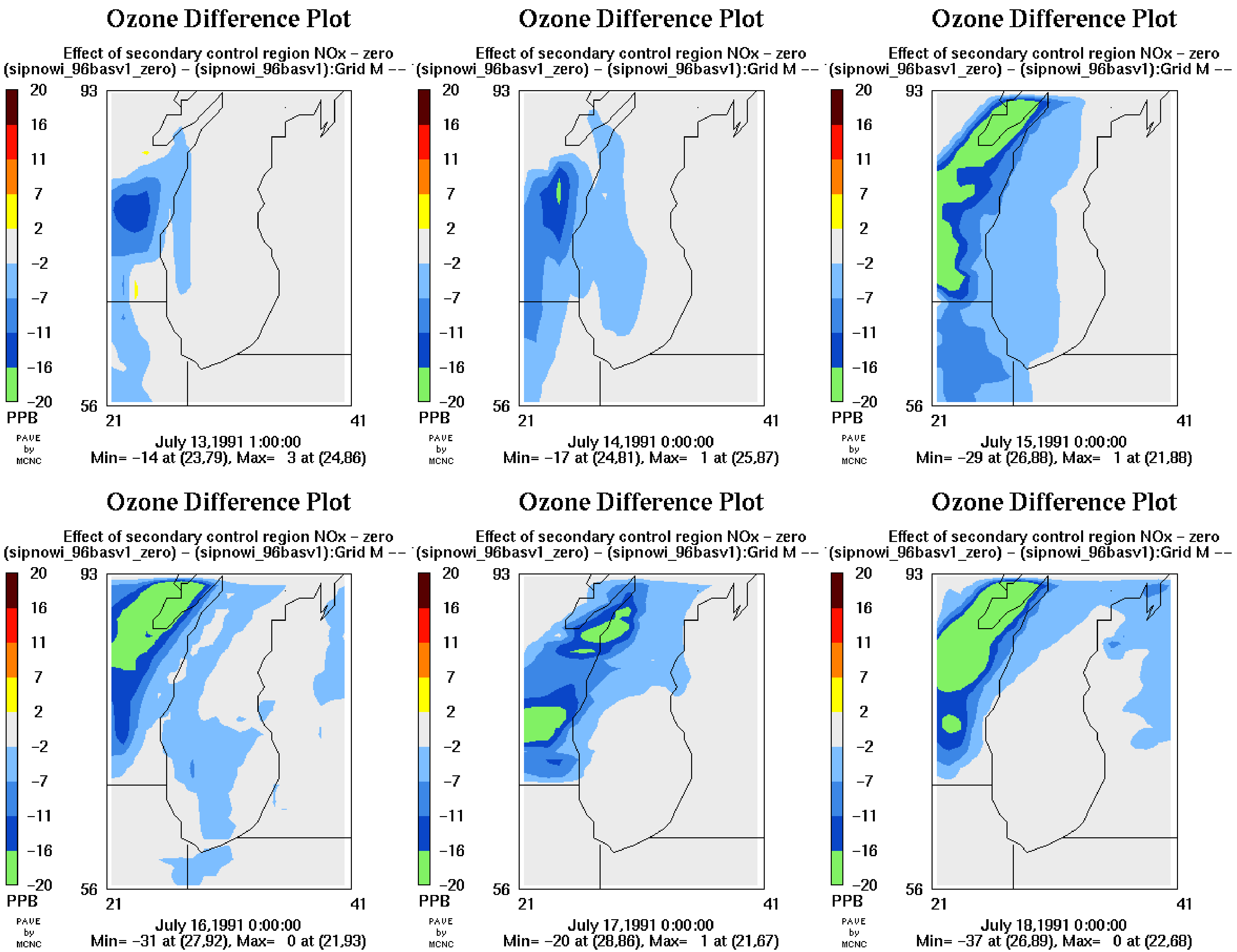
Plots showing the differences in peak 1-hour concentrations between the basecase and new control strategy were created. These plots were generated for both episodes (July 1991 and July 1995). The difference plots show the impact of the SOCR NOx emissions on ozone generation in the Grid M modeling domain.

Results from the July 13-21, 1991 episode (Figure 2) indicate ozone decreases, relative to the basecase values, of 14 ppb to 37 ppb. This means that NOx emissions in the SOCR are associated with generating ozone up to 37 ppb. The geographic orientation of the ozone plume attributed to these emissions varies with the meteorological conditions occurring on a particular day. However, for the majority of high ozone days during this episode, the affected area runs from Oshkosh - Appleton, through the Fox Valley to Green Bay, then northeastward to Door County.

Results for the July 7-18, 1995 episode (Figure 3) show ozone decreases from 9 to 26 ppb. Again, this means NOx emissions in the SOCR are associated with ozone concentrations of up to 26 ppb. Because this episode is of longer duration than the July 1991 episode more meteorological conditions were modeled. This results in the ozone plume affecting a wider area, from northern Illinois and Indiana, to central Michigan, and to the Fox Valley and Door County. Although magnitudes of the differences are less for this episode, the wind direction and speeds were higher, resulting in impacts as far away as central Michigan.

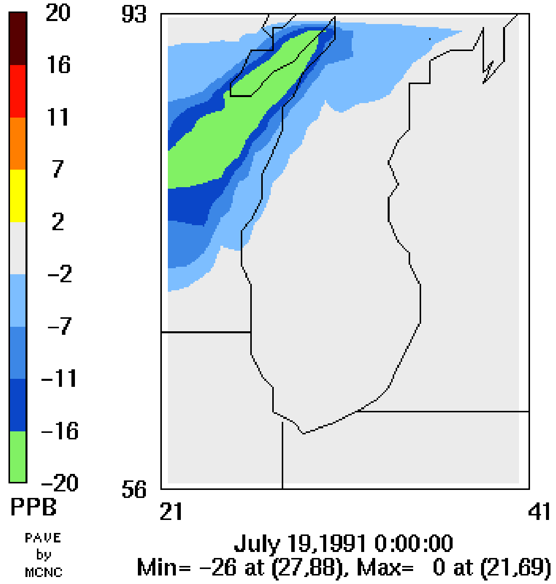
Modeling results show that, on average, ozone concentrations due to NOx emissions in the SOCR can range from 20-30 ppb. Occasionally, values can be higher. Depending on meteorological conditions, the area of impact can vary, from the SOCR itself to as far as central Michigan.

Figure 2


Ozone Difference Plot
Effect of secondary control region NOx – zero
(sipnowi_96basv1_zero) – (sipnowi_96basv1):Grid M --
20
16
11
7
2
-2
-7
-11
-16
-20
PPB
PAVE by MCNC
93
56
21
41
July 13,1991 1:00:00
Min= -14 at (23,79), Max= 3 at (24,86)
Ozone Difference Plot
Effect of secondary control region NOx – zero
(sipnowi_96basv1_zero) – (sipnowi_96basv1):Grid M --
July 14,1991 0:00:00
Min= -17 at (24,81), Max= 1 at (25,87)
Ozone Difference Plot
Effect of secondary control region NOx – zero
(sipnowi_96basv1_zero) – (sipnowi_96basv1):Grid M --
July 15,1991 0:00:00
Min= -29 at (26,88), Max= 1 at (21,88)
Ozone Difference Plot
Effect of secondary control region NOx – zero
(sipnowi_96basv1_zero) – (sipnowi_96basv1):Grid M --
July 16,1991 0:00:00
Min= -31 at (27,92), Max= 0 at (21,93)
Ozone Difference Plot
Effect of secondary control region NOx – zero
(sipnowi_96basv1_zero) – (sipnowi_96basv1):Grid M --
July 17,1991 0:00:00
Min= -20 at (28,86), Max= 1 at (21,67)
Ozone Difference Plot
Effect of secondary control region NOx – zero
(sipnowi_96basv1_zero) – (sipnowi_96basv1):Grid M --
July 18,1991 0:00:00
Min= -37 at (26,89), Max= 0 at (22,68)

Ozone Difference Plot

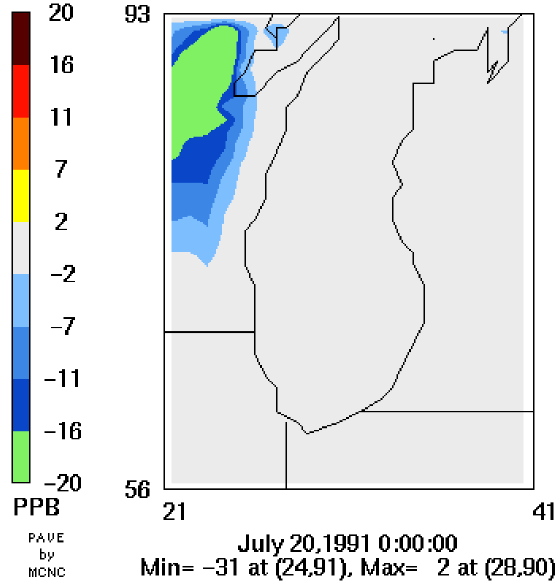
Effect of secondary control region NOx – zero
(sipnowi_96basv1_zero) – (sipnowi_96basv1):Grid M --



July 19,1991 0:00:00
Min= –26 at (27,88), Max= 0 at (21,69)

Ozone Difference Plot

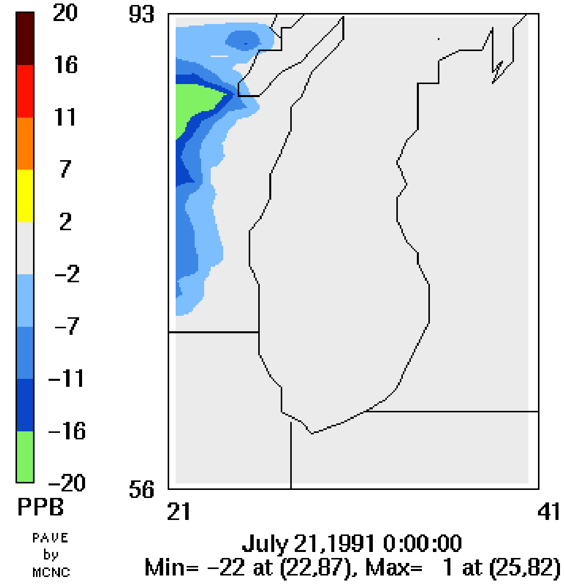
Effect of secondary control region NOx – zero
(sipnowi_96basv1_zero) – (sipnowi_96basv1):Grid M --



July 20,1991 0:00:00
Min= –31 at (24,91), Max= 2 at (28,90)

Ozone Difference Plot

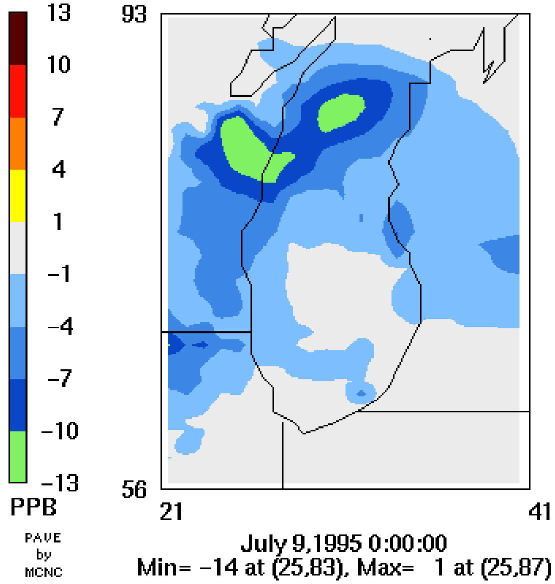
Effect of secondary control region NOx – zero
(sipnowi_96basv1_zero) – (sipnowi_96basv1):Grid M --



July 21,1991 0:00:00
Min= –22 at (22,87), Max= 1 at (25,82)

Ozone Difference Plot

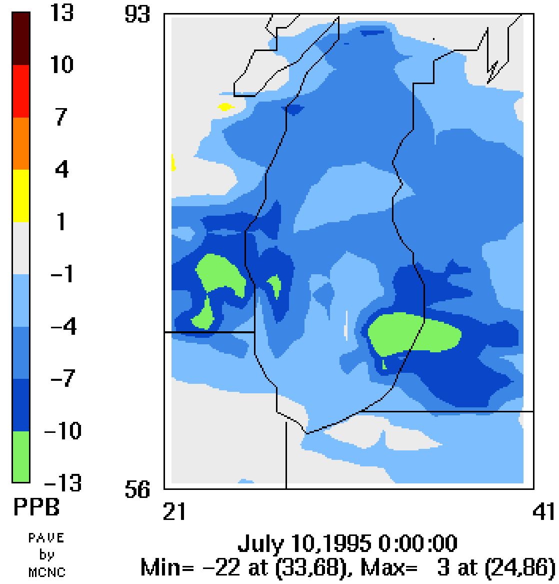
Effect of secondary control region NOx – zero
(sipnowi_96basv1_zero) – (sipnowi_96basv1):Grid M --



July 9,1995 0:00:00
Min= –14 at (25,83), Max= 1 at (25,87)

Ozone Difference Plot

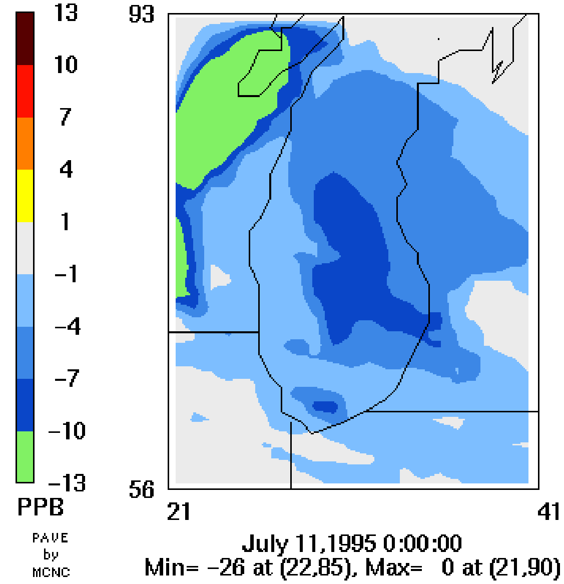
Effect of secondary control region NOx – zero
(sipnowi_96basv1_zero) – (sipnowi_96basv1):Grid M --



July 10,1995 0:00:00
Min= –22 at (33,68), Max= 3 at (24,86)

Ozone Difference Plot

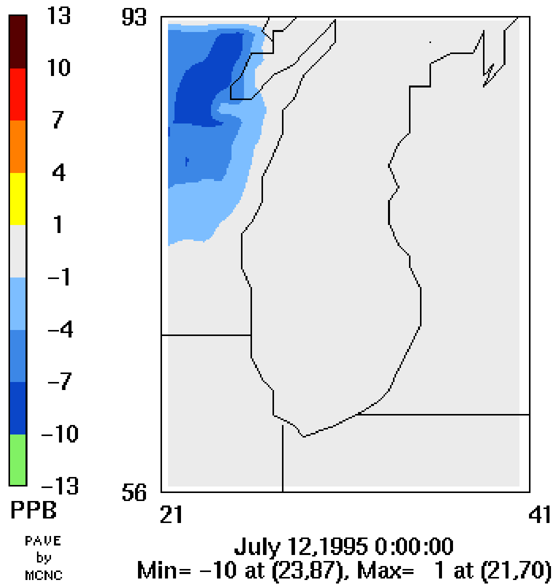
Effect of secondary control region NOx – zero
(sipnowi_96basv1_zero) – (sipnowi_96basv1):Grid M --



July 11,1995 0:00:00
Min= –26 at (22,85), Max= 0 at (21,90)

Ozone Difference Plot

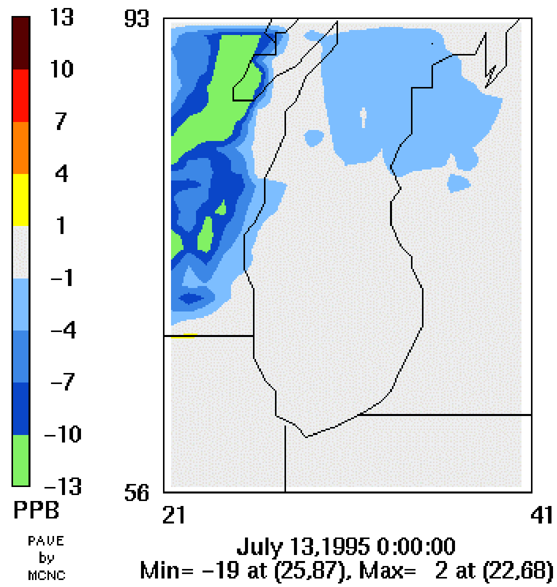
Effect of secondary control region NOx – zero
(sipnowi_96basv1_zero) – (sipnowi_96basv1):Grid M --



July 12,1995 0:00:00
Min= –10 at (23,87), Max= 1 at (21,70)

Ozone Difference Plot

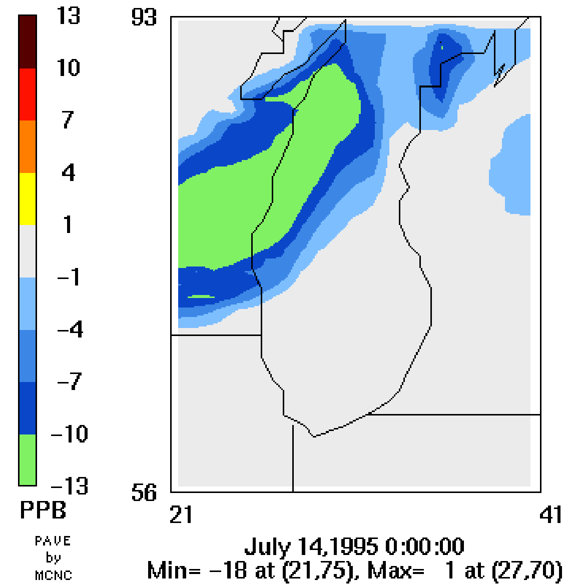
Effect of secondary control region NOx – zero
(sipnowi_96basv1_zero) – (sipnowi_96basv1):Grid M --



July 13,1995 0:00:00
Min= –19 at (25,87), Max= 2 at (22,68)

Ozone Difference Plot

Effect of secondary control region NOx – zero
(sipnowi_96basv1_zero) – (sipnowi_96basv1):Grid M --



July 14,1995 0:00:00
Min= –18 at (21,75), Max= 1 at (27,70)